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International Transmission Effects of Volatility Between Financial Markets in the G-7 since the Introduction of the Euro

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International Transmission Effects of Volatility between Financial Markets in the G-7 since the introduction of the Euro

Abstract

This paper investigates the nature of volatility spillovers between stock returns and a number of exchange rates changes for the G-7 countries for the 1996-2006 period. We divide our sample into a number of sub periods, prior to and after the introduction of the Euro, we use EGARCH modelling which takes into account whether bad news has the same impact on volatility as good news. Our results show that in terms of volatility spillover effects from stock returns to exchange rates returns, there is a large degree of consistency across countries and time periods with significant spillovers found for all countries, in all three periods, with the exception of Italy in the pre-Euro period. The impact of stock market volatility on exchange rates thus does not appear to have been altered significantly by the introduction of the Euro in the sense that the cross exchange rates against the \$, Yen, £ and CHF existed prior to the introduction of the Euro as well as after it across nearly all G-7 markets. In contrast, our results indicate that in terms of volatility spillovers from exchange rates to stock markets, the results are less consistent both across countries and over time but overall we find much less evidence supporting volatility spillovers from exchange rates to stock markets. There is however some commonality regarding which exchange rates we find significant volatility spillover effects to stock markets for the period after the Euro was introduced. The lack of significant spillovers from exchange rate changes to stock returns found here for some countries across a number of exchange rates is consistent with existing research in this area.

Introduction

The aim of this paper is to investigate the interdependence of stock returns and exchange rates changes for the G-7 financial markets and the main exchange rates, with the objective of identifying which currencies will generate a stronger impact in the financial markets in the G-7 before and after the introduction of the Euro. Several theoretical models have found empirical evidence that the exchange rate between two currencies is affected by stock price changes in the respective countries; for example, Zapatero (1995) shows that in fully integrated financial markets, there is an explicit linkage between the volatility of stock prices and the volatility of the exchange rate. More recently, Yang and Doong (2002) note that given the rapid integration and deregulation of international financial markets in recent years, exchange rates have become more sensitive to stock market innovations. A number of studies have investigated the extent of volatility spillovers between stock markets and exchange rates in the G-7 countries (see for example, Yang and Doong, 2004; Kanas, 2000, 2002). However no study to date has specifically investigated volatility spillovers between stock markets and exchange rates in the G7 since the introduction of the Euro. In addition to this there is a lack of evidence of studies studying this issue taking into account the effect of exchange rates other than for the domestic currency on the stock returns of these countries. Therefore, we attempt to address the gap in the literature in this area by conducting a in depth analysis of the relationship between these two variables, with the objective of also adding to the general literature in this area investigating spillovers between stock markets and exchange rates for a number of exchange rates. Current evidence for the G-7 has focused exclusively on spillovers between the domestic currency and the stock market, for this reason we analyse the

relationship between these two variables in a wider way. Section 1 sets out the theoretical and empirical evidence on the nature of linkages between stock markets and exchange rates. Section 2 describes of the methodology we use to assess the nature of volatility spillovers between the stock and foreign exchange markets, section 3 present our empirical results and we discuss our data and section 4 concludes the paper.

1. Literature Review

Several theoretical models have analysed the link between stock markets and currency markets. The asset market approach to exchange rate determination (Branson, 1983; Frankel, 1983) posits that causality will run from stock prices to exchange rate changes as expectations of financial asset price movements affect the dynamics of exchange rates. Smith (1992) derives an estimable equation for the exchange rate where the stock price is included as an explanatory variable. The goods market approach suggests causality runs in the opposite direction, from exchange rates to stock prices (Mundell, 1963, 1964; Dornbusch and Fisher, 1980). In these models, movements in exchange rates affect the international competitiveness of firms which affects real income and output and eventually stock prices.

Much of the available empirical evidence on the linkages between stock markets and exchange rates has concentrated on the first moments¹. Yang and Doong (2004) note that there is a dearth of empirical evidence that concentrates on the linkages between the second moments of the distribution of the variables. A number of studies however have examined the extent to which volatility from one stock market spills over into other stock markets or between different assets². Kanas (2000) was one of the first studies which analysed volatility spillovers from stock returns to exchange rate changes in the USA, the UK, Japan, Germany, France and Canada. He found evidence of spillovers from stock returns to exchange rate changes for all countries except Germany, suggesting that the asset approach to exchange rate determination is valid when formulated in terms of the second moments of the exchange rate distribution for the countries included in his analysis. Volatility spillovers from exchange rate changes to stock returns were insignificant for all countries. Assoé (2001) investigates the dynamic interrelationship between exchange rate changes and stock market performance in eleven emerging markets and five developed markets, using a trivariate Exponential-GARCH model. His results indicate that shocks in foreign exchange markets significantly increase volatility in emerging stock markets. He also found evidence of asymmetric volatility spillover from FX markets to stock markets for some of the countries that were included in his analysis. The asymmetric nature of volatility transmission suggest that investors in these markets react more to adverse innovations in foreign exchange markets than to positive shocks. Yang and Doong (2004) explored the nature of the mean and volatility transmission mechanism between stock and foreign exchange markets for the G-7 countries. The results point to significant volatility spillovers and an asymmetric effect from the stock market to the foreign exchange market for France, Italy, Japan and the US, suggesting integration between stock and foreign exchange markets in these countries. Kanas (2000) and Yang and Doong (2004) concentrate exclusively on the domestic currency and do not investigate the extent of spillovers from other currencies to the domestic stock market. Wu (2005) examines volatility spillovers between stock prices and exchange rates for Japan, South Korea, Indonesia, Philippines, Singapore, Thailand and Taiwan for the period 1997-2000, splitting the sample into crises and recovery periods. He found a bi-directional relationship between the volatility of stock returns and exchange rate changes during the recovery period in all countries except South Korea, as well as significant contemporaneous relationships between the two markets for most of the countries. Furthermore, he found volatility spillovers

¹ See for example Nieh and Lee (2001), Yau and Nieh (2006) for recent evidence on this topic.

² See also for example, Nelson (1991), Koutmos and Booth (1995), Laopodis (1998).

increased in the recovery period. Qayyum and Kemal (2006) examine volatility spillover between the stock market and the foreign exchange market in Pakistan, through a bivariate EGARCH model. Their results show that the behaviour of both the stock exchange and the foreign exchange markets are interlinked. The returns of one market are affected by the volatility of the other market. In particular the returns of the stock market are sensitive to the returns as well as the volatility of foreign exchange markets. They found evidence of strong relationship between the volatility of foreign exchange market and the volatility of returns in stock market. Leeves (2007) analyse the conditional volatility in stock returns in Indonesia over the period covered by the Asian crisis. He used three asymmetric models of conditional volatility (GJR, NGARCH and AGARCH), he found evidences of significant asymmetric impacts from conditional volatility shocks, with negative shocks causing greater volatility than positive shocks, during the Asian crisis. We add to the existing literature in this area by providing up to date evidence on this issue for the G-7 and provide new evidence on the extent to which volatility spillovers vary between different currencies and the domestic stock market in each country.

2. Data and Methodology

The analysis will be conducted with the purpose of investigating volatility spillovers between stock returns and exchange rate changes for the G-7 (Canada, France, Germany, Italy, Japan, UK and USA) for the period 1 January 1996 to 31 December 2006. . In order to analyse the relationship between these two variables, we split our sample into three sub samples which provide more detail and a better understanding of volatility spillovers between stock returns and exchange rates. Therefore, initially we which analyse the relationship between these two variables before the introduction of the Euro, so our first sub sample will analyse 1996-1998. Then we analyse the time period after the introduction of the Euro from 1999-2006. We are interested in examining whether the first years of the single currency in the European financial markets affected the relationship between our variables, so we split our sample into two sub periods; 1999-2001 covers the period that markets were working with the single currency but without physically being introduced. Finally we analyse from 2002-2006 where the Euro was physically introduced in the financial markets, allowing us to observe the behaviour of our variables when the Euro settled in European Monetary Union. The data set consists of daily closing values for the stock market indices in each country, as well as daily closing values for the exchange rates of each country against the Euro, DM, UK£, Swiss Franc (CHF), Japanese Yen and the US\$. We include these exchange rates to examine whether volatility spillovers are stronger from certain currencies during the sample period. The original data set was subject to some modifications, all holidays and other closing days were removed from the sample in order to avoid inconsistencies with the data set and also in order to avoid problems in the modelling estimation. Data was taken from DataStream and the Federal Reserve Statistic Release, giving a total of 2766 observations for each series. Following Kanas (2000) we use continuously compounded stock returns and exchange rate changes calculated as the first differences of the natural log. That is, $S_t = \ln(P_t^s) - \ln(P_{t-1}^s)$ and $E_t = \ln(P_t^e) - \ln(P_{t-1}^e)$.

As an initial step we provide descriptive statistics for stock returns and exchange rates, in order to summarise the statistical characteristics of our sample. We then proceed and perform a stationarity test on each of the relevant variables that are included in our analysis to ensure that the results from the analysis are not spurious. We apply the Dickey Fuller (DF) test, or Augmented Dickey-Fuller test (ADF) procedure if serial correlation is present. We also apply the Lagrange Multiplier (LMF) test, to ensure that a sufficient number of lags have been added in the ADF test to ensure that there is no serial correlation present and the results of the ADF test are valid. The LMF test is applied given that it is valid in the presence of lagged dependent variables as well as having the advantage of testing for first and higher orders of serial correlation. If our variables are non-stationary in levels, we then proceed and perform a cointegration test on our variables using the Johansen Cointegration test to

investigate the long-run relationship between Stock Prices and Exchange Rates. As Enders (2004) notes given that the results of the test can be quite sensitive to the lag length, the most common procedure is to estimate a Vector Autoregression (VAR) model on the undifferenced data in order to determine the lag length for the Johansen test. We estimate the lag selection tests up to 20 lags. In terms of choosing between the various lag length selection criteria we follow Johansen *et al.*(2000) who suggest that when different information criteria suggest different lag lengths, it is common practice to prefer Hannan-Quinn (HQ) criteria. Again, we ensure that the lag length selected for the VAR model is free from serial after performing by applying the LMF test to test for serial correlation up to the number of lags in the VAR model. There are five possible models to choose from for the Johansen test as follows.

$$H_2(r) : \Pi y_{t-1} + B x_t = \alpha B' y_{t-1} \quad (1)$$

$$H^*_1(r) : \Pi y_{t-1} + B x_t = \alpha (B' y_{t-1} + p_0) \quad (2)$$

$$H_1(r) : \Pi y_{t-1} + B x_t = \alpha (B' y_{t-1} + p_0) + \alpha_{\perp} \gamma_0 \quad (3)$$

$$H^*(r) : \Pi y_{t-1} + B x_t = \alpha (B' y_{t-1} + p_0 + p_1 t) + \alpha_{\perp} \gamma_0 \quad (4)$$

$$H(r) : \Pi y_{t-1} + B x_t = \alpha (B' y_{t-1} + p_0 + p_1 t) + \alpha_{\perp} (\gamma_0 + \gamma_1 t) \quad (5)$$

Equation 1 has no deterministic trends in the level data and no intercepts in the cointegrating equations. Equation 2 has no deterministic trends in the level data and the cointegrating equations have intercepts. Equation 3 has linear trends in the level data but the cointegrating equations only have intercepts. Equation 4 has linear trends in both the level data and the cointegrating equations, and equation 5 has quadratic trends in the level data and linear trends in the cointegrating equations. Harris and Sollis (2003) note that model 1 i.e. with no deterministic components in the data or cointegration relations, is unlikely to occur in practice, as generally an intercept is needed to take account of the units of measurement of the variables; they also note that model 5 with quadratic trends, is economically hard to justify, as if the variables are entered in logs, as they are in our model, as this would imply an every increasing or decreasing rate of change. This leaves a choice between models 2-4. Johansen (1992) suggests choosing the appropriate model according to the Pantula principle; all three models are estimated; the Pantula principle involves moving through each model for the null hypothesis of $r=0$, then $r=1$ etc., and picking the model where the null hypothesis is rejected for the first time. Chang and Caudill (2005) note that the λ_{trace} test statistic is more robustness to both skewness and excess kurtosis than the λ_{max} test statistic; for comparative purposes, we show both the results of the λ_{trace} and the λ_{max} test statistics.

We then proceed with our volatility analysis and apply a bivariate extension of the EGARCH (p,q) model in order to examine whether the volatility of stock returns affects and is affected by the volatility of exchange rate changes within each economy. The EGARCH specification (Nelson, 1991) is used in order to test whether the volatility spillover effects are asymmetric. For example, an asymmetric spillover from stock returns to exchange rate changes would suggest that the effect of “bad” stock market news on the exchange rate change is greater than the effect of “good” news. The model is specified as follows:

$$S_t = a_{s,0} + \sum_{i=1}^r a_{s,i} S_{t-i} + \sum_{i=1}^r a_{e,i} E_{t-i} + \beta_s \lambda_{s,t-1} + e_{s,t} \quad (6)$$

$$E_t = a_{e,0} + \sum_{i=1}^r a_{e,i} E_{t-i} + \sum_{i=1}^r a_{s,i} S_{t-i} + \beta_e \lambda_{e,t-1} + e_{e,t} \quad (7)$$

$$e_{s,t} / \Omega_{t-1} \approx N(0, \sigma_{s,t}^2)$$

$$e_{e,t} / \Omega_{t-1} \approx N(0, \sigma_{e,t}^2)$$

The conditional variances of stock returns and exchange rates changes are specified as follows:

$$\sigma_{S,t}^2 = \exp \left\{ c_{S,0} + \sum_{j=1}^{ps} b_{S,j} \log(\sigma_{S,t-j}^2) + \delta_{S,S} \left[\left| z_{S,t-1} \right| - E \left| z_{S,t-1} \right| + \theta_{S,Sz_{S,t-1}} \right] + \delta_{S,E} \left[\left| z_{E,t-1} \right| - E \left| z_{E,t-1} \right| + \theta_{S,Ez_{E,t-1}} \right] \right\} \quad (8)$$

$$\sigma_{E,t}^2 = \exp \left\{ c_{E,0} + \sum_{j=1}^{ps} b_{E,j} \log(\sigma_{E,t-j}^2) + \delta_{E,E} \left[\left| z_{E,t-1} \right| - E \left| z_{E,t-1} \right| + \theta_{E,Ez_{E,t-1}} \right] + \delta_{E,S} \left[\left| z_{S,t-1} \right| - E \left| z_{S,t-1} \right| + \theta_{E,Sz_{S,t-1}} \right] \right\} \quad (9)$$

$$\sigma_{S,E,T} = \rho_{S,E} \sigma_{S,t} \sigma_{E,t}$$

We summarise each of the relevant terms in equations (6-9) in Table 1.

Table 1 Description of Parameters Equations (6)-(9)

	Stock Returns	Exchange Rate Returns
Error correction terms (lagged residuals from the cointegrating regression of S_t, E_t)	$\lambda_{S,t-1}$	$\lambda_{E,t-1}$
Stochastic error terms	$e_{S,t}$	$e_{E,t}$
Information set at time $t-1$	Ω_{t-1}	Ω_{t-1}
Conditional (time varying) variances	$\sigma_{S,t}^2$	$\sigma_{E,t}^2$
Standardised residuals assumed to be normally distributed with 0 mean and variances of $\sigma_{S,t}^2, \sigma_{E,t}^2$	$z_{S,t} = e_{S,t} / \sigma_{S,t}$ $e_{S,t} / \Omega_{t-1} \sim N(0, \sigma_{S,t}^2)$	$z_{E,t} = e_{E,t} / \sigma_{E,t}$ $e_{E,t} / \Omega_{t-1} \sim N(0, \sigma_{E,t}^2)$
Persistence of Volatility	$\sum_{j=1}^{ps} b_{S,j}$	$\sum_{j=1}^{pE} b_{E,j}$
ARCH effect where the parameters $\theta_{S,S}, \theta_{E,E}$ allow this effect to be asymmetric	$\left[\left z_{S,t} \right - E \left z_{S,t} \right + \theta_{S,Sz_{S,t}} \right]$	$\left[\left z_{E,t} \right - E \left z_{E,t} \right + \theta_{E,Ez_{E,t}} \right]$
Volatility Spillover	$\delta_{S,E} \left[\left z_{E,t-1} \right - E \left z_{E,t-1} \right + \theta_{S,Ez_{E,t-1}} \right]$	$\delta_{E,S} \left[\left z_{S,t-1} \right - E \left z_{S,t-1} \right + \theta_{E,Sz_{S,t-1}} \right]$
Measures of spillovers	$\delta_{S,E}$	$\delta_{E,S}$
Asymmetry of Spillovers	$^3 \theta_{S,E}$	$\theta_{E,S}$
Correlation Coefficient for Standardised Residuals	$\rho_{S,E}$	$\rho_{E,S}$

We specify the number of lags for the conditional mean equations (6) and (7) using the HQ criterion; Griffin *et al* (2005) Andersen *et al* (2004) and Stulz *et al* (2002) all note that the Hannan-Quinn selection criterion is preferable to the more commonly used Akaike's Information Criteria (AIC), as the latter tends to overparameterize the models⁴. Next we apply the likelihood ratio (LR) test to determine the lag truncation length, p . We perform separate LR test on the stock returns and exchange rate conditional variance equations (8) and (9) to determine the optimal lag length for the EGARCH specification of each equation. Hamilton (1994) defines the LR test as follows:

³ $\theta_{S,E} < 0, \theta_{S,E} < 0$, implies that negative exchange rate shocks increase the volatility of stock returns more than positive shocks

⁴ For brevity here we do not report the number of lags selected for the conditional mean equations for stock prices and exchange rates for each period.

$2[L(\hat{\theta}) - L(\tilde{\theta})] \approx \chi^2(m)$, where $L(\hat{\theta})$ denotes the value of the log likelihood function at the unrestricted estimate and $L(\tilde{\theta})$ denotes the value of the log likelihood function of the restricted estimate. Bollerslev-Woolridge robust t -statistics are derived to take into account possible non-normality of the residuals. All results are generated using the EVIEWS statistical program.

3. Empirical Results

Our analysis begins by providing descriptive statistics for stock returns and exchange rates, in order to summarise the statistical characteristics of our sample which are set out in Tables 2 to 5. For the stock returns of each country for 1996-98 we found that the means are positive in all the cases, with the exception of the NIKKEI 225. During 1999-2001 the sample means of stock returns are positive in the case of Canada, France and the US, while for Germany, Italy, Japan and the UK stock returns means are negative. During 2002-2006 the means of all the indices are positive. The standard deviations of the stock returns provide information about the volatility of the markets during the three periods. In general, all the markets show higher volatility during the initial years of the introduction of the Euro on financial markets, that is during 1999 to 2001. The SD ranges from 1.23%(Dow Jones) to 1.58%(Dax 30). The standard deviations for 2002-2006 range from 0.81% (S&P/TSX Composite) to 1.61% (DAX 30). The skewness and kurtosis coefficients indicate that stock returns are leptokurtic relative to the normal distribution, which Caporale et al. (2002) note is a common finding for stock returns. The Jarque-Bera test also rejects the hypothesis that stock returns are normally distributed in all the cases.

The descriptive statistics for the exchange rate returns are presented for each country, to capture the behaviour of the exchange rates on an individual basis. Overall there is a wide variation in the sign and magnitude of the means and standard deviations both over time, across countries and across the various bilateral exchange rates we include in the analysis. For Canada, during 1996-1998 the means of the exchange rates are positive in the case of C\$/\$, C\$/£ and C\$/¥, while C\$/CHF and C\$/DM means are negative. During 1999-2001 the means for the C\$/€, C\$/¥ are positive while C\$/£, C\$/CHF and C\$/DM are negative, and during 2002-2006 the mean for all the exchange rates are negative. The SD shown that as with the stock returns, the exchange rates are more volatile during the first years of the introduction of the Euro on financial markets, the SD range from 0.36% (C\$/¥) to 0.79% (C\$/£).

For the period prior to the introduction of the Euro for France, the means are positive in the case of Franc/\$, Franc/£ and Franc/¥, while the means are negative for Franc/CHF and Franc/DM. For Germany, the means for D/\$, DM/£, DM/¥ are positive, while DM/CHF mean is negative. For Italy, for this period the means are positive for Lira/\$, Lira/£, while Lira/¥, Lira/CHF and Lira/DM are negative.

During 1999-2001 the €/¥ and €/£ means are negative while the €/€ and €/CHF are positive this situation reverses during 2002-2006 where the €/¥ and €/£ means are positive and the €/€ and €/CHF means are negative. As with Canada, we also found that in this case the volatility in the exchange rates is higher during the 1999-2001 than in the other periods, ranging from 0.24%(€/CHF) and 0.90% (€/¥).

For Japan during 1996-1998 the means for the ¥/\$, and ¥/£ are positive while ¥/CHF and ¥/DM are negative, during 1999-2001 the ¥/€ and ¥/CHF the means are negative while ¥/\$ and ¥/£ are positive, and finally during 2002-2006 the means are positive in all the cases with the exception of ¥/\$ which is negative. The volatility of these markets was higher during 1999-2001 period, as in the previous cases, with the SD range from 0.71% (¥/\$) to 1%(¥/CHF).

For the UK for 1996-1998 the means for all the exchange rates are negative. During 1999-2001 the means are positive in all the cases with the exception of £/CHF, and during 2002-2006 the means are negative in all cases. The SD coefficients indicates that the exchange markets were more volatile

during 1999-2001 than in the other periods, where volatility range from 0.51% (£/€ and £/\$) to 1% (£/¥).

For the US the mean coefficients are positive during 1996-1998 in all the cases, with the exception of \$/£. During 1999-2001 the means are negative in all the cases with the exception of £/£ were the means are positive, and finally during 2002-2006 the means are positive with the exception of \$/€ that is negative. The SD coefficients show that again the exchange rates were more volatile during 1999-2001 than in the rest of the period, ranging from 0.49% (\$/£) to 0.7%(\$/¥).

The skewness and kurtosis statistics for all countries and bilateral exchange rates in all periods indicate that the distribution of exchange rate returns in all the cases for all the countries are non-normal and the Jarque-Bera test also rejects the hypothesis of normally distributed returns for all periods for all exchange rates.

The results from the ADF tests are given in Tables 6 and 7. The values of the test statistics indicate that we can reject the null hypothesis of the existence of unit root in levels for all variables in all periods indicating that all series are $I(0)$.⁵ Given that all variables are integrated of the same order, and also given that they are $I(0)$ processes we proceed directly to perform our volatility analysis using EGARCH (p,q) modelling.

In order to establish the correct lag length for the EGARCH model, we apply the Likelihood Ratio test. The results from this test for each country are set out in Table 8. Dealing firstly with the stock return equations, for the 1996-1998 period, we chose the EGARCH (1,1) model for the DM/\$ for Germany and for the \$/£, \$/Yen and \$DM for the US. For the 1999-2001 period we chose the EGARCH (1,1) for Canada for the C\$/\$, C\$/Yen and C\$/CHF. For Germany and Japan for this period this model was also chosen for all bilateral exchanges rates. For the 2002-2006 period for France for the €/£ and €/Yen, as well as for Germany for the €/Yen and for Japan for all bilateral exchange rates the (1,1) model was selected on the basis of the LR results. For all countries for all other exchange rates for the EGARCH (2,1) model was selected for the stock return equation.

For the exchange rate equation, for the 1996-1998 period we selected the EGARCH (1,1) model for Canada for C\$/\$, for France for FR/DM, for Germany for DM./\$ and for Japan for Y/CHF. For the 2002-2006 period, again for Canada we selected the (1,1) model for C\$/£ and C\$/¥, for France and Italy for €/£, for the UK for £/€, \$/CHF and finally for the US for the \$/€ and \$/£. Again for all countries for all other exchange rates in each period, the EGARCH(2,1) model was chosen for the exchange rate equation.

The estimated parameters from the EGARCH estimation are set out in Tables 9-17, for the three periods of analysis (1996-1998, 1999-2001 and 2002-2006).

Firstly, in relation to the coefficients on the volatility persistence term, the results vary depending on the country, the equation but we find that the majority of terms are significant for both the stock returns and exchange rate changes. This is not surprising given that persistence is a feature of many financial markets data. Regarding the significance of volatility persistence in stock returns, Italy was the only country for which the volatility persistence term was significant in all periods across all bilateral exchange rates; France also showed consistency across all time periods for all exchange rates with only the €/CHF not significant in 2002-2006. There appears to be more consistency between the pre Euro period and the 2002-2006 period for certain countries; for example, for Canada and the UK, all bilateral exchange rates are significant for the stock return equation in both periods but insignificant for the 1998-2001 period. While all coefficients were significant across all exchange rates for Japan in the pre-Euro period, there was no significant persistence evident in after the introduction of the Euro. In contrast, there was no significant volatility persistence in the US apart from the \$/CHF prior to the Euro and for the 1999-2001 period, but for 2002 all bilateral exchange rates in the stock return. For the persistence of volatility of exchange rates, an interesting feature of our results which reflects our analysis of more than one exchange rate is that the persistence of volatility of exchange rates varies

⁵ The LMF test results indicated that the ADF tests were free from serial correlation; for brevity we do not show the test results here.

depending on which bilateral exchange rate is included in the EGARCH model. Overall, there appears to be more widespread persistence in the 1996-1998 period and the 2002-2006 period than the 1991-2001 period for Canada, Japan, Germany and Italy. Only for the US and France was there more significant volatility persistence across exchange rates in the 2002-2006 period than in the periods prior to this, while for the UK the 2002-2006 period showed a decline in the significance of volatility persistence across exchange rates compared to the earlier periods. Thus the impact of the introduction of the Euro on the persistence of the volatility of stock returns and exchange rates has not had a uniform impact across the financial markets in the G-7. Wu (2005) notes that a necessary condition for the volatility persistence terms to be stable is that the value of the estimated coefficients should be less than one; for our results, this applies in all cases for the three periods for the persistence terms for both stock returns and exchange rates where the magnitude of the coefficients are all less than one.

In terms of the coefficients for the volatility spillover effects, firstly there is a large degree of consistency across countries and time periods for spillovers from stock returns to exchange rate changes. We find significant spillovers at 5% level for Canada, France, Japan and the UK for all periods for all bilateral exchange rates. For Germany in the period prior to the introduction of the Euro the DM/\$ was the only exchange rate for which there was not significant volatility spillovers from the stock market with significant spillovers evident from the stock market to all exchange rates post 1999. Thus the volatility of stock returns has been an important influence and determinant of volatility of all bilateral exchange rates we included in our analysis in these countries. Furthermore, the impact of stock market volatility on exchange rates has not been altered significantly by the introduction of the Euro in the sense that the cross exchange rates against the \$, Yen, £ and CHF existed prior to the introduction of the Euro as well as after it across nearly all G-7 markets. In addition to this, we find that for the pre Euro period, Italy was the only country in the G-7 for which there was no volatility spillover effects from the stock market to any of the bilateral exchange rates included in our analysis. After the Euro was introduced, the \$/£ exchange rate was the only exchange rate where no volatility spillovers were evident from the US stock market at 5% level, although this was significant at 10% level.

The significant coefficients indicate that the volatility of stock returns was a determinant of the volatility of the exchange rate and that information contained in stock prices impacted on the behaviour of exchange rates in these markets. Significant coefficients are also indicative of integration between stock markets and exchange rate markets; given that the G-7 markets are the most developed financial markets globally, the existence of integration is not surprising. In addition, the lack of these spillovers in Italy in the pre Euro period can be taken as evidence that the stock and money markets in Italy were not as integrated as in other more developed G-7 countries. Furthermore, where the coefficients are insignificant indicates that prior to the introduction of the Euro there was some potential for diversification between stock markets and currency markets in these countries.

In terms of volatility spillovers from exchange rates to stock markets, the results are less significant across countries and over time. For the 1996-1998 period, Canada, Germany and Italy had no significant spillovers. For the other countries included in the analysis, there were a number of bilateral exchange rates where significant spillovers were evident from exchange rates to stock returns at 5% level; for the period prior to the introduction of the Euro, they were for France for the FR/DM, for Japan for the Yen/CHF, for the UK for the £/\$ and for the US for the \$/£ exchange rates. After the Euro there is some commonality regarding which exchange rates we find significant volatility spillover effects for stock markets. That is, for the €/Yen and Yen/CHF the volatility spillovers were significant for the stock markets in France, Germany and Italy, the Yen/€ and Yen/CHF for the Japanese stock market, the £/€ and £/CHF for the UK and the \$/\$ for the US. For the 2002-2006 period, again there were only a small number of all exchange rates included for which we observed significant volatility spillovers into stock markets; for Canada for the C\$/£, for Japan for Yen/£, for the UK for the £/€ and £/\$. No significant spillovers were evident in France, Germany or Italy.

The lack of significant spillovers from exchange rate changes to stock returns found here for some countries across a number of exchange rates is consistent with results from Jorion (1990) as well as with Yang and Doong (2005). Jorion (1990) explained the lack of spillovers as possibly due to positive exchange rate volatility on stock returns for some firms offsetting negative exchange rate volatility on stock returns for other firms to give an insignificant or weak effect overall. In addition to this, the use of instruments to hedge exchange rate risk, may reduce the impact of exchange rate volatility on stock markets; Grant and Marshall, 1997, and Bodnar *et al.* (1995) both note that the use of hedging instruments to ameliorate exchange rate risk is pervasive amongst larger companies which are the main components of national stock market indices. The lack of significant spillovers from exchange rates to stock markets in the pre Euro period could be indicative of wider use of hedging by firms listed on the stock markets in these countries than after the introduction of the Euro. It may also be the case that the adoption of the Euro brought greater volatility to certain stock markets given the global nature of the currency which they would not have been exposed to prior to the Euros introduction.

A positive sign on the spillover coefficient indicates that an increase in volatility in one market is associated with increased volatility in the other market while a negative coefficient indicates that increase volatility in one market is associated with decreased volatility in the other market. In our results, we found a mixture of positive and negative significant coefficients for the two spillover terms in all periods; this indicates that the impact of volatility from exchange rate markets to stock markets or *vice versa* is not constant either over time for the same country, or across countries for the same period of time.

For the asymmetric spillover effects from stock returns to exchange rates we found that the coefficients are significant in all the cases for all the periods. Analysing asymmetric spillover effects from exchange rates to stock returns we found some differences, during 1996-1998 the coefficients are significant in almost all the cases, with the exception of Canada where the C\$/DM is insignificant, France show an insignificant coefficient in the case of FR/\$, for Germany DM/\$ is insignificant and finally the \$/DM for US is insignificant as well. During 1999-2001 we found the same characteristics, in general terms the coefficients are significant but there are few exceptions in relation to the following countries where the coefficients are insignificant: in the case of Canada we found that the coefficients are insignificant for C\$/\$, C\$/£ and C\$/€, for France and Germany and Italy the €/£ and finally for the US the \$/CHF. Analysing the last period 2002-2006 our results show that again the coefficients are significant in almost all the cases, just few exceptions were found where the coefficients are insignificant, in the case of Japan the ¥/\$ and the ¥/£, for the UK the £/€ and for the US the \$/£ and the \$/¥. Thus the general significance of most of the asymmetry coefficients justifies the use of the EGARCH model to capture this asymmetry in the impact of good and bad news. The existence of insignificant coefficients indicates that the spillover effects in these instances are symmetric, that is that positive and negative shocks have the same impact on volatility.

The diagnostic tests on the standardised residuals are listed for each country in Table 18. The Jarque-Bera test indicates that we reject the hypothesis that the residuals are normally distributed. Hence, this justifies the use of the Bollerslev-Woolridge robust *t*-statistics. The Ljung-Box statistics for all three periods for all countries indicate that there are no residual linear or non linear dependencies. There are some exceptions where the coefficient was not significant but the problem was corrected after introducing more lags into the test. Finally to check the validity of the assumption of constant correlation adopted in the estimation of the bivariate models (Kanas, 2000), the LB statistics for the cross products of the standardised residuals from the stock returns equation and from the exchange rate equation are calculated and these statistics indicated that the assumption of constant correlation over time can be accepted.

Conclusions

Relationships between equity returns and exchange rates are of particular interest for academics and practitioners due to the fact that these two variables play a crucial role in portfolio and risk management. Equity returns and exchange rate movements may be used to hedge portfolios against currency movements, where risk management has to take into consideration the linkages between these to markets in order to design appropriate strategies.

This paper set out to examine the volatility linkages between stock returns and exchange rates in the G-7 markets. While there is a significant body of evidence which investigates the relationship between the first moments of exchange rates and stock returns, the evidence on volatility linkages between the two markets is scarce and has generally been confined to investigation of the relationship for stock returns and a single exchange rate. Our analysis was thus broader in scope than existing research in that we included a number of bilateral exchange rates in our analysis which permitted us to examine whether volatility spillovers exist to the same extent across exchange rates so increasing our understanding of the nature of integration between stock and exchange rate markets in the G-7 countries. In addition to this, no research to date has explicitly focused on the impact of the introduction of the Euro on volatility spillovers between these financial markets. In order to address this gap in the literature, we examined three main periods, covering the time period before the introduction of the Euro, immediately after the introduction of the Euro but when the currency was still not in circulation, and finally the period covering when the currency was physically introduced.

Our results overall show that the volatility of stock prices affects the volatility of exchange rates in a much more widespread way than the volatility of exchange rates affecting the volatility of stock prices. Our results are thus consistent with those of Kanas (2000) and Yang and Doong (2004) who both found evidence of volatility spillovers from stock returns to exchange rates but no evidences of spillovers in the opposite direction. The lack of significant spillovers in these markets indicates that there is potential for diversification between stock markets and currency markets in certain instances. The difference between our results and existing studies on volatility spillovers between exchange rates and stock markets could reflect the larger number of bilateral exchange rates included in our analysis. Thus further research along these lines is required in order to establish more comprehensively the true nature of spillovers from exchange rates to equity markets which should provide valuable information on the possibilities for diversifying holdings of stocks and currencies in investment portfolios, as well as the potential for hedging amongst these assets.

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Table 2 Descriptive Statistics Stock Returns

	Mean	SD	Skewness	Kurtosis	JB
1996-1998					
S&P/TSX Composite	0.000408	0.0092	-1.2067	11.7138	2568
CAC 40	0.000962	0.0133	-0.1264	5.6589	224
DAX 30	0.001027	0.0145	-0.3719	6.2860	357
MIB 30	5.24E-05	0.0127	-0.2050	6.1065	822
NIKKEI 225	-0.00048	0.0149	0.1413	5.7485	240
FTSE 100	0.000619	0.0101	-0.1328	4.8311	108
Dow Jones	0.00076	0.0109	-0.7291	9.0648	1222
1999-2001					
S&P/TSX Composite	0.000228	0.0133	-0.4666	6.2841	352
CAC 40	0.000145	0.0143	-0.1723	3.7704	22
DAX 30	-3.31E-05	0.0158	-0.1669	4.2393	52
MIB 30	-0.0002	0.0147	-0.2199	5.3724	183
NIKKEI 225	-0.00032	0.0151	0.0152	4.9564	120
FTSE 100	-0.00016	0.0127	-0.3770	4.5325	86
Dow Jones	0.000116	0.0123	-0.3880	5.7630	258
2002-2006					
S&P/TSX Composite	0.000425	0.008127	0.0097	5.6228	347
CAC 40	0.000152	0.0141	-0.0357	7.2778	958
DAX 30	0.000194	0.0161	-0.0582	6.7782	747
MIB 30	0.00021	0.0112	-0.1440	6.1939	538
NIKKEI 225	0.000391	0.0127	-0.2084	4.1589	79
FTSE 100	0.000153	0.0114	0.2547	11.4587	3504
Dow Jones	0.000172	0.0100	0.3669	6.9579	847

Table 3 Descriptive Statistics Exchange Rates 1996-1998

	Mean	SD	Skewness	Kurtosis	JB
CANADA					
C\$/	0.000165	0.0029	-0.0828	7.1026	530
C\$/£	0.000253	0.0055	-0.0605	4.9201	116
C\$/¥	5.29E-05	0.0087	0.7794	7.3918	682
C\$/CHF	-6.22E-05	0.0071	0.6768	5.0271	187
C\$/DM	-3.34E-05	0.0061	0.4390	4.1136	63
FRANCE					
FRANCS/\$	0.000173	0.0052	-0.2988	4.1836	55
FRANCS/£	0.000261	0.0053	-0.2789	4.0171	42
FRANCS/¥	6.13E-05	0.0077	0.6667	6.7006	486
FRANCS/CHF	-5.38E-05	0.0029	0.0289	4.6822	89
FRANCS/DM	-2.50E-05	0.0011	-0.2162	6.0925	306
GERMANY					
DM/\$	0.000198	0.0053	-0.2665	4.1385	50
DM/£	0.000286	0.0052	-0.2564	3.6515	22
DM/¥	8.63E-05	0.0077	0.6796	6.7852	508
DM/CHF	-2.88E-05	0.0029	0.0380	4.9698	122
ITALY					
LIRA/\$	6.91E-05	0.0049	-0.1731	4.0160	36
LIRA/£	0.000157	0.0051	-0.2416	3.8240	29
LIRA/¥	-4.29E-05	0.0078	0.7519	6.8662	541
LIRA/CHF	-0.00016	0.0039	0.3086	5.4278	197
LIRA/DM	-0.00013	0.0027	0.1394	10.1224	1596
JAPAN					
¥/\$	0.000112	0.0083	-1.0488	8.9635	1256
¥/£	0.0002	0.0087	-0.5002	5.9988	314
¥/CHF	-0.00012	0.0078	-0.5877	5.9964	325
¥/DM	-8.63E-05	0.0077	-0.6796	6.7852	508
UK					
£/\$	-8.76E-05	0.0047	0.1766	5.6793	229
£/¥	-0.0002	0.0087	0.5002	5.9988	314
£/CHF	-0.00032	0.0060	0.2784	3.9091	36
£/DM	-0.00029	0.0052	0.2564	3.6515	22
US					
\$/£	8.76E-05	0.0046	-0.1765	5.6793	229
\$/¥	-0.00023	0.0062	0.45614	4.6274	109
\$/CHF	-0.00011	0.0082	1.0487	8.9635	1256
\$/DM	-0.0002	0.0052	0.2665	4.1385	50

Table 4 Descriptive Statistics Exchange Rates 1999-2001

	Mean	SD	Skewness	Kurtosis	JB
CANADA					
C\$/€	0.000604	0.0073	-0.2090	3.6311	17
C\$/£	6.08E-05	0.0036	-0.1017	3.6845	15
C\$/¥	-0.00013	0.0061	0.1749	3.7087	19
C\$/¥	-0.00017	0.0079	0.0648	4.3551	56
C\$/CHF	-0.0002	0.0076	0.2368	3.7611	24
EURO					
€/£	-0.00038	0.0066	0.2486	3.9753	38
€/¥	-0.0002	0.0053	0.0808	4.0327	34
€/¥	0.000169	0.0090	-0.0593	4.1008	38
€/CHF	0.000118	0.0024	0.6117	12.3531	2792
JAPAN					
¥/€	-0.00017	0.0090	0.0593	4.1008	38
¥/\$	0.00023	0.0071	-0.1587	4.8328	104
¥/£	4.37E-05	0.0081	0.0760	4.4216	62
¥/CHF	-1.97E-05	0.0100	-0.0175	4.5574	73
UK					
£/€	0.000185	0.0051	0.0059	3.8378	21
£/\$	0.000193	0.0051	-0.0601	3.8565	22
£/¥	3.82E-05	0.0100	2.0150	19.3181	8299
£/CHF	-4.87E-05	0.0085	0.1817	3.9171	29
US					
\$/€	0.000376	0.00664	-0.24884	3.9724	37
\$/£	-0.00017	0.004915	0.150059	3.4898	10
\$/¥	-0.00021	0.007	0.157536	5.1265	145
\$/CHF	-0.00026	0.006686	0.273988	3.8228	31

Table 5 Descriptive Statistics Exchange Rates 2002-2006

	Mean	SD	Skewness	Kurtosis	JB
CANADA					
C\$/€	-0.00042	0.0071	0.1276	3.0984	4
C\$/£	-0.00027	0.0051	0.0323	3.3647	7
C\$/¥	-1.18E-05	0.0058	-0.0984	3.4803	14
C\$/¥	-0.00018	0.0078	0.1178	3.5324	17
C\$/CHF	-1.49E-05	0.0083	-0.0631	3.5365	15
FRANCE					
€/£	0.000302	0.0058	-0.1429	3.4419	14
€/¥	5.99E-05	0.0038	0.0831	4.0029	54
€/¥	-0.00022	0.0055	0.3238	4.4597	133
€/CHF	-6.50E-05	0.0021	0.3025	4.2286	98
GERMANY					
€/£	0.000302	0.0058	-0.1429	3.4419	14
€/¥	5.99E-05	0.0038	0.0831	4.0029	54
€/¥	-0.00022	0.0055	0.3238	4.4597	133
€/CHF	-6.50E-05	0.0021	0.3025	4.2286	98
ITALY					
€/£	0.000302	0.0058	-0.1429	3.4419	14
€/¥	5.99E-05	0.0038	0.0831	4.0029	54
€/¥	-0.00022	0.0055	0.3238	4.4597	133
€/CHF	-6.50E-05	0.0021	0.3025	4.2286	98
JAPAN					
¥/€	0.000219	0.0055	-0.3238	4.4597	133
¥/\$	-8.62E-05	0.0059	-0.2830	4.5441	136
¥/£	0.000167	0.0057	-0.5124	5.2745	314
¥/CHF	0.000164	0.0091	-0.2452	3.4915	24
UK					
£/€	-0.00026	0.0054	0.1466	4.0860	62
£/\$	-0.00026	0.0054	0.0839	4.0850	59
£/¥	-0.00021	0.0089	0.0092	4.2362	75
£/CHF	-0.00018	0.0087	0.1027	3.3903	9
US					
\$/€	-0.0003	0.005794	0.141897	3.4401	14
\$/£	0.000244	0.005221	-0.12246	3.6344	24
\$/¥	8.31E-05	0.005858	0.330416	4.5867	154
\$/CHF	0.000236	0.006529	-0.03263	3.4612	11

Table 6 Augmented Dickey-Fuller Test Results

	1996-1998	1999-2001	2002-2006
Stock Returns			
S&P/TSX Composite	-6.36*	-19.91*	-34.10*
CAC 40	-9.05*	-26.47*	-9.79*
DAX 30	-6.55*	-27.13*	-8.53*
MIB 30	-16.68*	-11.95*	-13.64*
NIKKEI 225	-21.84*	-28.30*	-13.62*
FTSE 100	-7.02*	-17.68*	-11.89*
Dow Jones	-27.14*	-20.50*	-8.48*
Exchange Rates			
CANADA			
C\$/	-13.75*	n/a	n/a
C\$/£	-19.72*	n/a	n/a
C\$/¥	-11.56*	n/a	n/a
C\$/CHF	-26.82*	n/a	n/a
C\$/DM	-27.00*	n/a	n/a
FRANCE			
FRANCS/\$	-27.26*	n/a	n/a
FRANCS/£	-27.90*	n/a	n/a
FRANCS/¥	-25.11*	n/a	n/a
FRANCS/CHF	-26.59*	n/a	n/a
FRANCS/DM	-24.45*	n/a	n/a
GERMANY			
DM/\$	-10.57*	n/a	n/a
DM/£	-10.79*	n/a	n/a
DM/¥	-26.54*	n/a	n/a
DM/CHF	-11.04*	n/a	n/a
ITALY			
Lira/\$	-27.28*	n/a	n/a
Lira/£	-15.45*	n/a	n/a
Lira/¥	-25.26*	n/a	n/a
Lira/CHF	-20.34*	n/a	n/a
Lira/DM	-29.39*	n/a	n/a
JAPAN			
¥/€	n/a	-26.54*	-14.21*
¥/\$	-7.00*	-27.48*	-35.81*
¥/£	-11.43*	-26.23*	-12.42*
¥/CHF	-25.69*	-29.21*	-21.28*
¥/DM	-25.30*	n/a	n/a
UK			
£/€	n/a	-25.74*	-33.28*
£/\$	-26.39*	-26.18*	-33.82*
£/¥	-11.43*	-16.55*	-35.06*
£/CHF	-27.29*	-24.96*	-34.11*
£/DM	-15.17*	n/a	n/a
US			
\$/€	n/a	-10.54*	-6.72*
\$/£	-26.39*	-13.30*	-34.85*
\$/¥	-7.00*	-28.26*	-36.33*
\$/CHF	-26.70*	-26.86*	-37.84*
\$/DM	-27.28*	n/a	n/a

Note: * Indicates significant at 1% level

Table 7 Augmented Dickey-Fuller Test Results: Post Euro

	1999-2001	2002-2006
Exchange Rates		
CANADA		
C\$/€	-25.26*	-34.07*
C\$/£	-12.53*	-35.34*
C\$/¥	-27.57*	-33.82*
C\$/¥	-28.01*	-28.90*
C\$/CHF	-27.30*	-23.27*
FRANCE		
€/£	-10.57*	-6.73*
€/¥	-10.79*	-17.64*
€/¥	-26.54*	-14.21*
€/CHF	-11.04*	-35.70*
€/£	-10.57*	-6.73*
GERMANY		
€/£	-10.57*	-6.73*
€/¥	-10.79*	-17.64*
€/¥	-26.54*	-14.21*
€/CHF	-11.04*	-35.70*
ITALY		
€/£	-10.57*	-6.73*
€/¥	-10.79*	-17.64*
€/¥	-26.54*	-14.21*
€/CHF	-11.04*	-35.70*

Note: * Indicates significant at 1% level

Table 8 Likelihood Ratio Test Results

Canada					
1996-1998	C\$/	C\$/£	C\$/¥	C\$/CHF	C\$/DM
Stock Returns	0.256	0.336	0.06	0.398	0.18
Exchange Rates	0.48	0.044	0.97	0.781	18.317*
1999-2001	C\$/€	C\$/	C\$/£	C\$/¥	C\$/CHF
Stock Returns	12.084	11.238	9.998*	10.868*	10.11*
Exchange Rates	0.057	1.258	0.152	0.794	0.19
2002-2006	C\$/€	C\$/	C\$/£	C\$/¥	C\$/CHF
Stock Returns	0.402	0.246	0.612	0.29	0.210
Exchange Rates	0	0.656	7.38*	0.07	0.016
France					
1996-1998	FR/\$	FR/£	FR/¥	FR/CHF	FR/DM
Stock Returns	1.364	0.922	1.142	1.458	0.084
Exchange Rates	16.93	3.84	1.912	3.594	14.84*
1999-2001	€/	€/£	€/¥	€/CHF	
Stock Returns	0.2022	0.0728	0.195	0.488	
Exchange Rates	2.28	0.492	1.092	0.022	
2002-2006	€/	€/£	€/¥	€/CHF	
Stock Returns	7.706*	7.256	6.908*	2.734	
Exchange Rates	7.8488*	0.056	0.756	0.0256	
Germany					
1996-1998	DM/\$	DM/£	DM/¥	DM/CHF	
Stock Returns	1.386	8.046*	5.64	6.142	
Exchange Rates	16.602*	2.99	2.718	6.158	
1999-2001	€/	€/£	€/¥	€/CHF	
Stock Returns	12.441*	12.02*	14.864*	11.568*	
Exchange Rates	1.738	0.592	1.574	0.048	
2002-2006	€/	€/£	€/¥	€/CHF	
Stock Returns	5.852	5.68	15.92*	4.484	
Exchange Rates	4.205	0.086	0.8	0.1006	
Italy					
1996-1998	LIRA/\$	LIRA/£	LIRA/¥	LIRA/CHF	LIRA/DM
Stock Returns	1.56	2.12	2.11	1.94	3.81
Exchange Rates	4.95	0.13	0.25	2.49	5.52
1999-2001	€/	€/£	€/¥	€/CHF	
Stock Returns	0.238	0.507	1.192	1.77	
Exchange Rates	1.962	0.414	3.092	0.916	
2002-2006	€/	€/£	€/¥	€/CHF	
Stock Returns	1.42	1.158	1.432	0.372	
Exchange Rates	38.155*	0.14	1.058	0.042	
Japan					
1996-1998	¥/\$	¥/£	¥/CHF	¥/DM	
Stock Returns	0.056	0.206	0.204	0.254	
Exchange Rates	0.284	1.664	17.536*	4.994	
1999-2001	¥/€	¥/\$	¥/£	¥/CHF	
Stock Returns	13.73*	13.746*	14.554*	12.384*	
Exchange Rates	3.66	2.718	1.118	1.026	
2002-2006	¥/€	¥/\$	¥/£	¥/CHF	
Stock Returns	11.028*	10.152*	10.284*	11.32*	
Exchange Rates	2.266	2.142	4.073	3.78	
UK					
1996-1998	£/\$	£/¥	£/CHF	£/DM	
Stock Returns	1.28	1.94	1.27	1.286	
Exchange Rates	1.76	3.35	5.47	1.76	
1999-2001	£/€	£/\$	£/¥	£/CHF	
Stock Returns	0.061	2.591	0.131	0.01	
Exchange Rates	0.453	0.01	0.276	0.002	
2002-2006	£/€	£/\$	£/¥	£/CHF	

Stock Returns	1.376	1.12	0.762	0.292
Exchange Rates	33.848*	5.076	0.403	23.294*
US				
1996-1998	\$/£	\$/¥	\$/CHF	\$/DM
Stock Returns	6.892*	6.612*	5.706	6.934*
Exchange Rates	3.608	0.006	1.022	4.783
1999-2001	\$/€	\$/£	\$/¥	\$/CHF
Stock Returns	0	0.088	0.102	0.004
Exchange Rates	1.132	0.401	1.932	2.324
2002-2006	\$/€	\$/£	\$/¥	\$/CHF
Stock Returns	5.202	4.946	3.202	5.382
Exchange Rates	43.93*	43.012*	0.693	5.969

Note: H_0 : EGARCH (1,1), H_1 : EGARCH(2,1) The 5% critical value for the LR test distributed as χ^2 with 2 degrees of freedom is 5.99. Note: * Indicates significant at 1% level

Table 9 EGARCH RESULTS VOLATILITY PERSISTENCE 1996-1998

Canada	C\$/	C\$/¥	C\$/DM	C\$/CHF	C\$/£
Stock Returns	0.2749 (0.000)	0.2083 (0.000)	0.2766 (0.000)	0.2706 (0.000)	0.2828 (0.000)
Exchange Rates	0.1335 (0.004)	0.2671 (0.002)	0.2173 (0.004)	0.1132 (0.038)	0.0866 (0.005)
France	FR/\$	FR/£	FR/¥	FR/CHF	FR/DM
Stock Returns	0.1279 (0.000)	0.1314 (0.000)	0.1270 (0.000)	0.1278 (0.000)	0.1322 (0.000)
Exchange Rates	0.0171 (0.837)	0.0569 (0.0386)	0.1826 (0.000)	0.0436 (0.088)	0.6480 (0.000)
Germany	DM/\$	DM/£	DM/¥	DM/CHF	
Stock Returns	0.1345 (0.000)	-0.0596 (0.4952)	0.1538 (0.000)	-0.0314 (0.7285)	
Exchange Rates	-0.1973 (0.652)	-0.1532 (0.026)	-0.1936 (0.000)	-0.1417 (0.0311)	
Italy	LIRA/CHF	LIRA/¥	LIRA/DM	LIRA/£	LIRA/\$
Stock Returns	0.2081 (0.000)	0.2652 (0.000)	0.1914 (0.000)	0.2522 (0.000)	0.2534 (0.000)
Exchange Rates	0.0303 (0.207)	0.2463 (0.006)	0.1422 (0.000)	0.1098 (0.002)	0.1059 (0.003)
Japan	¥/\$	¥/£	¥/CHF	¥/DM	
Stock Returns	0.0450 (0.033)	0.0607 (0.008)	0.0528 (0.0130)	0.0483 (0.0215)	
Exchange Rates	0.2261 (0.0235)	0.2589 (0.004)	0.1903 (0.093)	0.1523 (0.000)	
UK	£/\$	£/¥	£/CHF	£/DM	
Stock Returns	0.0741 (0.002)	0.0851 (0.001)	0.0873 (0.001)	0.0862 (0.001)	
Exchange Rates	-0.0017 (0.891)	0.2637 (0.002)	0.0549 (0.107)	0.0638 (0.017)	
US	\$/£	\$/¥	\$/CHF	\$/DM	
Stock Returns	-0.0332 (0.741)	-0.0306 (0.760)	0.1396 (0.005)	-0.0381 (0.723)	
Exchange Rates	0.0063 (0.647)	0.2147 (0.017)	0.0425 (0.570)	-0.0863 (0.287)	

Table 10 EGARCH RESULTS VOLATILITY PERSISTENCE 1999-2001

Canada	C\$/	C\$/¥	C\$/CHF	C\$/£	C\$/€
Stock Returns	-0.11603 (0.286)	-0.1227 (0.237)	-0.1101 (0.279)	-0.1016 (0.327)	-0.1172 (0.304)
Exchange Rates	-0.1667 (0.159)	0.0292 (0.189)	-0.0409 (0.274)	0.0959 (0.220)	-0.0225 (0.746)
France	€/	€/£	€/¥	€/CHF	
Stock Returns	0.1021 (0.028)	0.0966 (0.042)	0.0978 (0.027)	0.0939 (0.041)	
Exchange Rates	-0.1106 (0.072)	0.2804 (0.001)	0.1108 (0.068)	0.1558 (0.002)	
Germany	€/	€/£	€/¥	€/CHF	
Stock Returns	-0.1973 (0.013)	-0.1532 (0.080)	-0.1936 (0.021)	-0.1417 (0.109)	
Exchange Rates	-0.1122 (0.103)	0.2794 (0.001)	0.0965 (0.092)	0.1614 (0.001)	
Italy	€/CHF	€/¥	€/£	€/	
Stock Returns	0.2301 (0.001)	0.2535 (0.000)	0.2627 (0.000)	0.2671 (0.000)	
Exchange Rates	0.1536 (0.003)	0.1058 (0.079)	0.2543 (0.003)	-0.1050 (0.124)	
Japan	¥/€	¥/\$	¥/£	¥/CHF	
Stock Returns	-0.1268 (0.2795)	-0.1209 (0.272)	-0.1261 (0.251)	-0.1059 (0.085)	
Exchange Rates	0.0929 (0.097)	0.0430 (0.066)	0.0171 (0.503)	-0.1059 (0.334)	
UK	£/€	£/\$	£/¥	£/CHF	
Stock Returns	0.0691 (0.059)	0.0689 (0.106)	0.0599 (0.106)	0.0660 (0.073)	
Exchange Rates	0.0858 (0.211)	0.1377 (0.115)	0.1879 (0.000)	0.0728 (0.130)	
US	\$/€	\$/£	\$/¥	\$/CHF	
Stock Returns	0.0550 (0.147)	0.0860 (0.238)	0.0388 (0.292)	0.0540 (0.124)	
Exchange Rates	-0.0537 (0.272)	0.0860 (0.238)	0.0516 (0.028)	-0.0557 (0.458)	

Table 11 EGARCH RESULTS VOLATILITY PERSISTENCE 2002-2006

Canada	C\$/	C\$/¥	C\$/CHF	C\$/£	C\$/€
Stock Returns	0.0886 (0.001)	0.0794 (0.004)	0.0821 (0.002)	0.0871 (0.002)	0.0981 (0.001)
Exchange Rates	0.1044 (0.014)	0.0548 (0.044)	0.1240 (0.000)	0.0371 (0.597)	0.0455 (0.386)
France	€/	€/£	€/¥	€/CHF	
Stock Returns	-0.0568 (0.492)	-0.0618 (0.417)	-0.0672 (0.406)	0.0947 (0.000)	
Exchange Rates	-0.1165 (0.115)	0.0402 (0.005)	0.0466 (0.029)	0.0957 (0.001)	
Germany	€/	€/£	€/¥	€/CHF	
Stock Returns	0.1116 (0.000)	0.1063 (0.000)	-0.0230 (0.781)	0.1035 (0.000)	
Exchange Rates	0.0596 (0.005)	0.0377 (0.008)	0.0459 (0.036)	0.0914 (0.002)	
Italy	€/CHF	€/¥	€/£	€/	
Stock Returns	0.0660 (0.000)	0.0774 (0.000)	0.0741 (0.000)	0.0832 (0.000)	
Exchange Rates	0.0919 (0.001)	0.0488 (0.029)	0.0447 (0.002)	-0.0934 (0.209)	
Japan	¥/€	¥/\$	¥/£	¥/CHF	
Stock Returns	-0.0693 (0.359)	-0.0437 (0.581)	-0.0461 (0.555)	-0.0606 (0.442)	
Exchange Rates	0.0491 (0.019)	-0.0040 (0.962)	0.0942 (0.259)	0.1363 (0.007)	
UK	£/€	£/\$	£/¥	£/CHF	
Stock Returns	0.0814 (0.000)	0.0883 (0.000)	0.0741 (0.000)	0.0720 (0.000)	
Exchange Rates	0.1052 (0.070)	-0.0158 (0.131)	0.0226 (0.431)	-0.0887 (0.233)	
US	\$/€	\$/£	\$/¥	\$/CHF	
Stock Returns	0.0663 (0.000)	0.0654 (0.000)	0.0585 (0.001)	0.0664 (0.000)	
Exchange Rates	-0.0843 (0.254)	0.1561 (0.007)	0.0136 (0.873)	0.0544 (0.007)	

Table 12 EGARCH RESULTS VOLATILITY SPILLOVERS 1996-1998

Canada	C\$/	C\$/¥	C\$/DM	C\$/CHF	C\$/£
Stock Returns	-0.1079 (0.005)	-0.0585 (0.023)	-0.0998 (0.010)	-0.0987 (0.010)	-0.0954 (0.008)
Exchange Rates	0.0147 (0.577)	0.0834 (0.067)	0.0744 (0.145)	0.0458 (0.356)	0.0583 (0.121)
France	FR/\$	FR/£	FR/¥	FR/CHF	FR/DM
Stock Returns	-0.0531 (0.017)	-0.0655 (0.003)	-0.0599 (0.010)	-0.0635 (0.003)	-0.0688 (0.002)
Exchange Rates	-0.0309 (0.537)	0.0270 (0.117)	0.0208 (0.558)	0.0265 (0.229)	0.1147 (0.018)
Germany	DM/\$	DM/£	DM/¥	DM/CHF	
Stock Returns	-0.0339 (0.170)	-0.0750 (0.005)	-0.0494 (0.040)	-0.0603 (0.018)	
Exchange Rates	-0.0367 (0.441)	0.0176 (0.247)	0.0128 (0.716)	0.0362 (0.255)	
Italy	Lira/\$	Lira/£	Lira/¥	Lira/CHF	Lira/DM
Stock Returns	-0.0204 (0.495)	-0.0376 (0.303)	-0.0141 (0.627)	-0.0341 (0.327)	-0.0376 (0.290)
Exchange Rates	-0.0195 (0.074)	0.0601 (0.157)	0.0162 (0.577)	0.0174 (0.419)	0.0121 (0.692)
Japan	¥/\$	¥/£	¥/CHF	¥/DM	
Stock Returns	-0.1320 (0.000)	-0.1324 (0.000)	-0.1364 (0.000)	-0.1416 (0.000)	
Exchange Rates	-0.0586 (0.1997)	-0.0587 (0.307)	-0.1899 (0.005)	-0.0116 (0.736)	
UK	£/\$	£/¥	£/CHF	£/DM	
Stock Returns	-0.0516 (0.000)	-0.0653 (0.000)	-0.0596 (0.000)	-0.0629 (0.000)	
Exchange Rates	-0.0402 (0.035)	0.0580 (0.304)	-0.0063 (0.686)	-0.0136 (0.352)	
US	\$/£	\$/¥	\$/CHF	\$/DM	
Stock Returns	-0.1577 (0.000)	-0.1601 (0.000)	-0.1363 (0.000)	-0.1583 (0.000)	
Exchange Rates	0.0493 (0.019)	0.0392 (0.384)	0.0904 (0.072)	-0.0332 (0.506)	

Table 13 EGARCH RESULTS VOLATILITY SPILLOVERS 1999-2001

Canada	C\$/	C\$/¥	C\$/CHF	C\$/£	C\$/€
Stock Returns	-0.1014 (0.000)	-0.1031 (0.000)	-0.1078 (0.000)	-0.1093 (0.000)	-0.0619 (0.029)
Exchange Rates	-0.0693 (0.259)	0.0252 (0.117)	-0.0054 (0.794)	0.0244 (0.556)	0.0180 (0.743)
France	€/	€/£	€/¥	€/CHF	
Stock Returns	-0.0954 (0.002)	-0.0805 (0.009)	-0.0806 (0.011)	-0.0671 (0.024)	
Exchange Rates	-0.0210 (0.639)	-0.0753 (0.255)	0.0824 (0.008)	0.1331 (0.008)	
Germany	€/	€/£	€/¥	€/CHF	
Stock Returns	-0.1217 (0.001)	-0.1131 (0.002)	-0.1106 (0.002)	-0.1075 (0.002)	
Exchange Rates	-0.0158 (0.723)	-0.0800 (0.232)	0.0665 (0.023)	0.1333 (0.008)	
Italy	€/CHF	€/¥	€/£	€/	
Stock Returns	-0.0815 (0.002)	-0.0928 (0.018)	-0.0961 (0.011)	-0.1009 (0.008)	
Exchange Rates	-0.1292 (0.011)	-0.0770 (0.013)	-0.0793 (0.229)	-0.0143 (0.745)	
Japan	¥/€	¥/\$	¥/£	¥/CHF	
Stock Returns	-0.0939 (0.0505)	-0.0896 (0.004)	-0.0894 (0.004)	-0.0840 (0.001)	
Exchange Rates	-0.0617 (0.031)	-0.0349 (0.094)	-0.0242 (0.3777)	-0.0840 (0.006)	
UK	£/€	£/\$	£/¥	£/CHF	
Stock Returns	-0.1015 (0.052)	-0.1166 (0.035)	-0.1117 (0.041)	-0.1101 (0.039)	
Exchange Rates	-0.1385 (0.002)	-0.0556 (0.227)	-0.0024 (0.956)	0.0515 (0.073)	
US	\$/€	\$/£	\$/¥	\$/CHF	
Stock Returns	-0.1372 (0.000)	0.0740 (0.0831)	-0.1324 (0.000)	-0.1306 (0.000)	
Exchange Rates	0.0270 (0.560)	0.0740 (0.083)	0.0323 (0.136)	-0.0004 (0.989)	

Table 14 EGARCH RESULTS VOLATILITY SPILLOVERS 2002-2006

Canada	C\$/	C\$/¥	C\$/CHF	C\$/£	C\$/€
Stock Returns	-0.0803 (0.000)	-0.0850 (0.000)	-0.0836 (0.000)	-0.0833 (0.000)	-0.0939 (0.000)
Exchange Rates	-0.0081 (0.656)	-0.0104 (0.657)	0.0073 (0.751)	0.0145 (0.012)	0.0977 (0.097)
France	€/	€/£	€/¥	€/CHF	
Stock Returns	-0.1149 (0.000)	-0.1304 (0.000)	-0.1156 (0.000)	-0.1297 (0.000)	
Exchange Rates	0.0032 (0.814)	0.0043 (0.727)	0.0032 (0.863)	-0.0023 (0.925)	
Germany	€/	€/£	€/¥	€/CHF	
Stock Returns	-0.0949 (0.000)	-0.1109 (0.000)	-0.1083 (0.000)	-0.0991 (0.000)	
Exchange Rates	0.0069 (0.571)	0.0053 (0.664)	0.0004 (0.982)	-0.0041 (0.866)	
Italy	€/CHF	€/¥	€/£	€/	
Stock Returns	-0.0983 (0.000)	-0.0923 (0.000)	-0.0996 (0.000)	-0.0868 (0.000)	
Exchange Rates	0.0022 (0.925)	-0.0031 (0.867)	0.0035 (0.775)	0.0032 (0.799)	
Japan	¥/€	¥/\$	¥/£	¥/CHF	
Stock Returns	-0.0506 (0.0477)	-0.0598 (0.025)	-0.0595 (0.026)	-0.0583 (0.029)	
Exchange Rates	0.0007 (0.971)	0.0241 (0.682)	-0.1276 (0.033)	-0.0055 (0.892)	
UK	£/€	£/\$	£/¥	£/CHF	
Stock Returns	-0.1205 (0.000)	-0.1189 (0.000)	-0.1244 (0.000)	-0.1278 (0.000)	
Exchange Rates	0.0958 (0.041)	-0.0340 (0.000)	0.0218 (0.2887)	-0.0024 (0.757)	
US	\$/€	\$/£	\$/¥	\$/CHF	
Stock Returns	-0.0802 (0.000)	-0.0810 (0.000)	-0.0852 (0.000)	-0.0777 (0.000)	
Exchange Rates	-0.0080 (0.494)	-0.1030 (0.020)	-0.0662 (0.272)	-0.0035 (0.801)	

Table 15 EGARCH RESULTS ASYMMETRIC SPILLOVERS 1996-1998

Canada	C\$/	C\$/¥	C\$/DM	C\$/CHF	C\$/£
Stock Returns	0.9642 (0.000)	0.9742 (0.000)	0.9665 (0.000)	0.9674 (0.000)	0.9660 (0.000)
Exchange Rates	0.9874 (0.000)	0.9027 (0.000)	-0.1972 (0.598)	0.8954 (0.000)	0.9896 (0.000)
France	FR/\$	FR/£	FR/¥	FR/CHF	FR/DM
Stock Returns	0.9899 (0.000)	0.9907 (0.000)	0.9893 (0.000)	0.9902 (0.000)	0.9876 (0.000)
Exchange Rates	-0.3573 (0.104)	0.9926 (0.000)	0.9804 (0.000)	0.9811 (0.000)	0.9507 (0.000)
Germany	DM/\$	DM/£	DM/¥	DM/CHF	
Stock Returns	0.9931 (0.000)	0.9843 (0.000)	0.9895 (0.000)	0.9859 (0.000)	
Exchange Rates	-0.4816 (0.289)	0.9930 (0.000)	0.9846 (0.000)	0.9767 (0.000)	
Italy	Lira/\$	Lira/£	Lira/¥	Lira/CHF	Lira/DM
Stock Returns	0.9613 (0.000)	0.9355 (0.000)	0.9634 (0.000)	0.9406 (0.000)	0.9351 (0.000)
Exchange Rates	0.9945 (0.000)	0.9390 (0.000)	0.9983 (0.000)	0.9829 (0.000)	0.9749 (0.000)
Japan	¥/\$	¥/£	¥/CHF	¥/DM	
Stock Returns	0.9874 (0.000)	0.9856 (0.000)	0.9870 (0.000)	0.9861 (0.000)	
Exchange Rates	0.9405 (0.000)	0.9097 (0.000)	0.5479 (0.000)	0.9867 (0.000)	
UK	£/\$	£/¥	£/CHF	£/DM	
Stock Returns	0.9947 (0.000)	0.9937 (0.000)	0.9948 (0.000)	0.9943 (0.000)	
Exchange Rates	0.9934 (0.000)	0.9102 (0.000)	0.9871 (0.000)	0.9924 (0.000)	
US	\$/£	\$/¥	\$/CHF	\$/DM	
Stock Returns	0.9372 (0.000)	0.9399 (0.000)	0.9615 (0.000)	0.9475 (0.000)	
Exchange Rates	0.9964 (0.000)	0.9554 (0.000)	0.7299 (0.000)	-0.4999 (0.472)	

Table 16 EGARCH RESULTS ASYMMETRIC SPILLOVERS 1999-2001

Canada	C\$/\\$	C\$/¥	C\$/CHF	C\$/£	C\$/€
Stock Returns	0.9385 (0.000)	0.9398 (0.000)	0.9413 (0.000)	0.9365 (0.000)	0.9682 (0.000)
Exchange Rates	0.3974 (0.285)	0.9778 (0.000)	0.9169 (0.000)	-0.6604 (0.047)	-0.7229 (0.329)
France	€/\\$	€/£	€/¥	€/CHF	
Stock Returns	0.9415 (0.000)	0.9437 (0.000)	0.9484 (0.000)	0.9483 (0.000)	
Exchange Rates	-0.8955 (0.000)	-0.0025 (0.994)	0.9047 (0.000)	0.9597 (0.000)	
Germany	€/\\$	€/£	€/¥	€/CHF	
Stock Returns	0.9181 (0.000)	0.9084 (0.000)	0.9152 (0.000)	0.9118 (0.000)	
Exchange Rates	-0.8885 (0.000)	-0.0042 (0.990)	0.9204 (0.000)	0.9614 (0.000)	
Italy	€/CHF	€/¥	€/£	€/\\$	
Stock Returns	0.9426 (0.000)	0.9385 (0.000)	0.9375 (0.000)	0.9371 (0.000)	
Exchange Rates	0.9608 (0.000)	0.9054 (0.000)	0.0176 (0.963)	-0.8917 (0.000)	
Japan	¥/€	¥/\\$	¥/£	¥/CHF	
Stock Returns	0.9325 (0.000)	0.9337 (0.000)	0.9325 (0.000)	0.9391 (0.000)	
Exchange Rates	0.9236 (0.000)	0.9795 (0.000)	0.9611 (0.000)	0.9391 (0.000)	
UK	£/€	£/\\$	£/¥	£/CHF	
Stock Returns	0.9306 (0.000)	0.9173 (0.000)	0.9214 (0.000)	0.9183 (0.000)	
Exchange Rates	-0.7294 (0.000)	-0.7077 (0.000)	0.9824 (0.000)	0.9439 (0.000)	
US	\\$/€	\\$/£	\\$/¥	\\$/CHF	
Stock Returns	0.9662 (0.000)	-0.7464 (0.000)	0.9643 (0.000)	0.9698 (0.000)	
Exchange Rates	-0.9072 (0.000)	-0.7464 (0.000)	0.9831 (0.000)	0.7417 (0.102)	

Table 17 EGARCH RESULTS ASYMMETRIC SPILLOVERS 2002-2006

Canada	C\$/	C\$/¥	C\$/CHF	C\$/£	C\$/€
Stock Returns	0.9658 (0.000)	0.9649 (0.000)	0.9658 (0.000)	0.9651 (0.000)	0.9562 (0.000)
Exchange Rates	0.9763 (0.000)	0.9703 (0.000)	0.9570 (0.000)	0.9923 (0.000)	-0.6080 (0.002)
France	€/	€/£	€/¥	€/CHF	
Stock Returns	0.9858 (0.000)	0.9844 (0.000)	0.9864 (0.000)	0.9858 (0.000)	
Exchange Rates	0.9824 (0.000)	0.9983 (0.000)	0.9946 (0.000)	0.9669 (0.000)	
Germany	€/	€/£	€/¥	€/CHF	
Stock Returns	0.9878 (0.000)	0.9871 (0.000)	0.9857 (0.000)	0.9874 (0.000)	
Exchange Rates	0.9868 (0.000)	0.9986 (0.000)	0.9947 (0.000)	0.9662 (0.000)	
Italy	€/CHF	€/¥	€/£	€/	
Stock Returns	0.9880 (0.000)	0.9878 (0.000)	0.9869 (0.000)	0.9877 (0.000)	
Exchange Rates	0.9670 (0.000)	0.9944 (0.000)	0.9975 (0.000)	0.9842 (0.000)	
Japan	¥/€	¥/\$	¥/£	¥/CHF	
Stock Returns	0.9750 (0.000)	0.9698 (0.000)	0.9695 (0.000)	0.9699 (0.000)	
Exchange Rates	0.9943 (0.000)	-0.2654 (0.894)	0.0039 (0.991)	0.8993 (0.000)	
UK	£/€	£/\$	£/¥	£/CHF	
Stock Returns	0.9872 (0.000)	0.9877 (0.000)	0.9876 (0.000)	0.9876 (0.000)	
Exchange Rates	-0.2906 (0.368)	0.9963 (0.000)	0.9589 (0.000)	0.9936 (0.000)	
US	\$/€	\$/£	\$/¥	\$/CHF	
Stock Returns	0.9925 (0.000)	0.9924 (0.000)	0.9930 (0.000)	0.9925 (0.000)	
Exchange Rates	0.9889 (0.000)	-0.0108 (0.970)	-0.3173 (0.687)	0.9810 (0.000)	

Table 18 Diagnostic Test on EGARCH models

Canada					
1996-1998	C\$/	C\$/¥	C\$/DM	C\$/CHF	C\$/£
Stock Returns					
JB	389	757	395	429	324
LB(20)	50.584 (0.000)	53.727 (0.000)	54.751 (0.000)	53.283 (0.000)	53.897 (0.000)
LB ² (20)	12.507 (0.898)	10.434 (0.960)	11.927 (0.919)	12.919 (0.881)	12.595 (0.894)
Exchange Rates					
JB	46	187	74	245	67
LB(20)	19.539 (0.487)	24.336 (0.228)	18.246 (0.571)	12.319 (0.905)	28.708 (0.094)
LB ² (20)	15.77 (0.731)	8.0373 (0.992)	36.107 (0.015)	12.992 (0.878)	13.47 (0.856)
Cross Products					
LB(20)	17.635 (0.611)	29.27 (0.083)	18.606 (0.548)	14.511 (0.804)	16.194 (0.705)
LB ² (20)	14.614 (0.798)	49.117 (0.000)*	20.332 (0.437)	11.218 (0.940)	2.9102 (1.000)
1999-2001	C\$/	C\$/¥	C\$/CHF	C\$/£	C\$/€
Stock Returns					
JB	83	86	73	82	56
LB(20)	18.661 (0.544)	18.547 (0.551)	17.752 (0.604)	18.386 (0.562)	25.749 (0.174)
LB ² (20)	6.9292 (0.997)	7.6807 (0.994)	7.5534 (0.991)	7.2135 (0.996)	7.6796 (0.994)
Exchange Rates					
JB	18	18	21	16	17
LB(20)	22.689 (0.304)	14.777 (0.789)	31.638 (0.047)	26.505 (0.150)	32.342 (0.040)
LB ² (20)	44.719 (0.001)*	12.831 (0.885)	15.091 (0.771)	17.999 (0.587)	25.543 (0.181)
Cross Products					
LB(20)	15.066 (0.773)	15.896 (0.723)	14.089 (0.826)	18.742 (0.539)	17.966 (0.590)
LB ² (20)	4.1503 (1.000)	11.937 (0.918)	4.692 (1.000)	9.877 (0.970)	12.113 (0.912)
2002-2006	C\$/	C\$/¥	C\$/CHF	C\$/£	C\$/€
Stock Returns					
JB	22	25	28	23	28
LB(20)	15.884 (0.724)	14.465 (0.806)	13.859 (0.838)	14.316 (0.814)	12.92 (0.881)
LB ² (20)	18.499 (0.555)	18.248 (0.571)	19.627 (0.481)	19.883 (0.465)	13.238 (0.867)
Exchange Rates					
JB	9	20	7	7	3
LB(20)	16.257 (0.701)	49.509 (0.000)*	77.078 (0.000)*	20.578 (0.422)	14.005 (0.830)
LB ² (20)	28.365 (0.101)	16.122 (0.709)	18.381 (0.562)	27.212 (0.129)	59.112 (0.000)*
Cross Products					
LB(20)	21.431 (0.372)	16.748 (0.669)	23.474 (0.266)	20.657 (0.418)	32.503 (0.038)
LB ² (20)	12.337 (0.904)	11.382 (0.936)	6.741 (0.997)	15.677 (0.736)	28.945 (0.089)

*LB²(32):53.005(0.011); LB²(9):18.074(0.034); LB(41):64.861(0.010); LB²(9):16.766(0.053)

Table 19 Diagnostic Test on EGARCH models

France					
1996-1998	FR/\$	FR/£	FR/¥	FR/CHF	FR/DM
Stock Returns					
JB	11	4	7	10	7
LB(20)	23.11 (0.283)	23.531 (0.263)	19.37 (0.498)	21.582 (0.364)	22.482 (0.315)
LB ² (20)	7.9367 (0.992)	7.8246 (0.993)	6.7154 (0.998)	7.6451 (0.994)	7.8243 (0.993)
Exchange Rates					
JB	19	39	114	44	66
LB(20)	12.361 (0.903)	14.973 (0.778)	15.39 (0.754)	12.926 (0.881)	76.764 (0.000)*
LB ² (20)	36.008 (0.015)	20.254 (0.442)	12.692 (0.890)	17.608 (0.613)	13.205 (0.868)
Cross Products					
LB(20)	17.791 (0.601)	21.004 (0.397)	20.382 (0.434)	28.745 (0.093)	14.915 (0.781)
LB ² (20)	23.717 (0.255)	30.86 (0.057)	10.219 (0.964)	22.426 (0.18)	46.381 (0.000)*
1999-2001	€/ \$	€/ £	€/ ¥	€/ CHF	
Stock Returns					
JB	4	7	5	7	
LB(20)	24.666 (0.215)	21.273 (0.381)	20.502 (0.427)	21.265 (0.382)	
LB ² (20)	29.966 (0.070)	30.199 (0.067)	28.182 (0.105)	25.834 (0.171)	
Exchange Rates					
JB	44	28	26	392	
LB(20)	37.236 (0.011)	30.548 (0.061)	21.012 (0.396)	21.817 (0.351)	
LB ² (20)	39.916 (0.005)*	39.213 (0.006)*	16.808 (0.665)	14.392 (0.810)	
Cross Products					
LB(20)	32.065 (0.043)	28.389 (0.101)	16.104 (0.710)	19.462 (0.492)	
LB ² (20)	18.399 (0.561)	19.35 (0.499)	8.3721 (0.989)	4.3363 (1.000)	
2002-2006	€/ \$	€/ £	€/ ¥	€/ CHF	
Stock Returns					
JB	13	17	13	6	
LB(20)	25.928 (0.168)	22.238 (0.328)	24.27 (0.231)	22.211 (0.329)	
LB ² (20)	22.69 (0.304)	20.096 (0.452)	17.824 (0.599)	18 (0.616)	
Exchange Rates					
JB	15	52	133	95	
LB(20)	31.227 (0.052)	22.607 (0.308)	31.314 (0.051)	15.604 (0.741)	
LB ² (20)	20.226 (0.444)	23.067 (0.286)	13.627 (0.849)	12.875 (0.883)	
Cross Products					
LB(20)	56.758 (0.000)*	33.204 (0.032)	35.872 (0.016)	26.591 (0.147)	
LB ² (20)	36.13 (0.015)	56.568 (0.000)*	18.915 (0.527)	10.732 (0.953)	

*LB²(29):48.588(0.013); LB²(24):42.949(0.010), LB²(22):39.664(0.012); LB(13):27.359(0.011), LB²(20):20.027(0.067)

Table 20 Diagnostic Test on EGARCH models

Germany				
1996-1998	DM/\$	DM/£	DM/¥	DM/CHF
Stock Returns				
JB	14	10	16	15
LB(20)	20.324 (0.438)	18.855 (0.531)	19.441 (0.493)	17.805 (0.600)
LB ² (20)	17.356 (0.630)	14.312 (0.814)	14.403 (0.809)	10.094 (0.966)
Exchange Rates				
JB	45	32	122	78
LB(20)	15.335 (0.757)	15.316 (0.758)	18.458 (0.557)	9.9396 (0.969)
LB ² (20)	15.131 (0.769)	16.535 (0.683)	10.94 (0.948)	7.8623 (0.993)
Cross Products				
LB(20)	17.878 (0.595)	16.525 (0.684)	18.333 (0.565)	24.856 (0.207)
LB ² (20)	8.362 (0.989)	42.49 (0.000)*	4.6912 (1.000)	32.65 (0.037)
1999-2001	€/ \$	€/ £	€/ ¥	€/ CHF
Stock Returns				
JB	25	7	9	4
LB(20)	26.326 (0.155)	24.048 (0.240)	23.657 (0.258)	23.181 (0.280)
LB ² (20)	14.727 (0.792)	22.581 (0.310)	21.721 (0.356)	24.475 (0.222)
Exchange Rates				
JB	43	28	30	386
LB(20)	36.744 (0.013)	30.946 (0.056)	21.015 (0.936)	22.57 (0.310)
LB ² (20)	35.205 (0.019)	35.908 (0.016)	16.443 (0.689)	16.11 (0.710)
Cross Products				
LB(20)	29.798 (0.073)	28.851 (0.091)	7.9922 (0.967)	12.198 (0.909)
LB ² (20)	46.009 (0.001)*	44.686 (0.000)*	59.215 (0.000)	4.1369 (1.000)
2002-2006	€/ \$	€/ £	€/ ¥	€/ CHF
Stock Returns				
JB	13	19	13	9
LB(20)	21.871 (0.348)	18.607 (0.547)	21.222 (0.384)	18.232 (0.572)
LB ² (20)	14.605 (0.799)	10.43 (0.960)	10.754 (0.952)	13.172 (0.870)
Exchange Rates				
JB	11	48	143	104
LB(20)	27.739 (0.116)	22.121 (0.334)	32.216 (0.041)	16.027 (0.715)
LB ² (20)	24.533 (0.220)	22.368 (0.321)	11.979 (0.917)	13.763 (0.842)
Cross Products				
LB(20)	50.826 (0.000)*	35.423 (0.018)	28.179 (0.105)	29.039 (0.087)
LB ² (20)	42.541 (0.002)*	19.792 (0.471)	25.965 (0.167)	13.963 (0.832)

*LB²(29):49.719(0.01); LB²(12):8.884(0.712); LB(29):48.757(0.012); LB²(2.112)(0.953); LB(14):19.432(0.149); LB(14):6.907(0.938)

Table 21 Diagnostic Test on EGARCH models

Italy					
1996-1998	LIRA/CHF	LIRA/¥	LIRA/DM	LIRA/£	LIRA/\$
Stock Returns					
JB	15	31	20	26	43
LB(20)	23.848 (0.249)	23.466 (0.266)	29.863 (0.0072)	23.745 (0.254)	22.535 (0.312)
LB ² (20)	19.997 (0.458)	16.592 (0.679)	17.702 (0.607)	17.048 (0.650)	14.667 (0.795)
Exchange Rates					
JB	46	137	106	21	38
LB(20)	11.204 (0.941)	15.531 (0.745)	31.792 (0.046)	19.333 (0.500)	13.682 (0.846)
LB ² (20)	19.695 (0.477)	6.613 (0.989)	18.171 (0.576)	19.550 (0.486)	37.219 (0.011)
Cross Products					
LB(20)	24.965 (0.203)	10.677 (0.954)	29.421 (0.080)	29.74 (0.074)	12.336 (0.904)
LB ² (20)	8.8149 (0.985)	0.5807 (1.000)	8.7528 (0.986)	4.9999 (1.000)	0.6451 (1.000)
1999-2001					
	€/CHF	€/¥	€/£	€/ \$	
Stock Returns					
JB	6	9	6	5	
LB(20)	27 (0.142)	23.386 (0.270)	23.145 (0.282)	23.009 (0.288)	
LB ² (20)	16.578 (0.680)	18.114 (0.580)	16.437 (0.689)	19.109 (0.515)	
Exchange Rates					
JB	411	31	28	48	
LB(20)	22.291 (0.325)	20.469 (0.429)	28.594 (0.096)	30.995 (0.055)	
LB ² (20)	15.365 (0.755)	16.068 (0.712)	40.263 (0.005)*	41.967 (0.003)*	
Cross Products					
	€/CHF	€/¥	€/£	€/ \$	
LB(20)	23.862 (0.248)	13.011 (0.877)	20.214 (0.445)	29.864 (0.072)	
LB ² (20)	10.566 (0.957)	23.052 (0.286)	42.596 (0.000)*	23.923 (0.246)	
2002-2006					
	€/CHF	€/¥	€/£	€/ \$	
Stock Returns					
JB	43	86	85	58	
LB(20)	16.12 (0.709)	18.992 (0.522)	17.646 (0.611)	16.745 (0.669)	
LB ² (20)	10.368 (0.961)	7.4098 (0.995)	9.1597 (0.981)	8.4719 (0.988)	
Exchange Rates					
JB	93	136	51	11	
LB(20)	17.629 (0.612)	31.613 (0.048)	21.434 (0.372)	28.688 (0.094)	
LB ² (20)	12.27 (0.906)	13.515 (0.854)	20.009 (0.457)	20.979 (0.398)	
Cross Products					
	€/CHF	€/¥	€/£	€/ \$	
LB(20)	21.918 (0.345)	34.941 (0.020)	19.785 (0.471)	48.811 (0.000)*	
LB ² (20)	16.934 (0.657)	15.265 (0.761)	11.048 (0.945)	40.239 (0.000)*	

Table 22 Diagnostic Test on EGARCH models

Japan				
1996-1998	¥/\$	¥/£	¥/CHF	¥/DM
Stock Returns				
JB	19	19	20	18
LB(20)	22.284 (0.325)	21.886 (0.347)	22.615 (0.308)	21.775 (0.353)
LB ² (20)	21.559 (0.365)	21.049 (0.394)	19.74 (0.474)	20.219 (0.444)
Exchange Rates				
JB	326	90	62	123
LB(20)	19.902 (0.464)	16.514 (0.684)	24.144 (0.236)	16.816 (0.665)
LB ² (20)	7.9373 (0.992)	16.626 (0.677)	33.145 (0.033)	15.829 (0.727)
Cross Products				
LB(20)	33.631 (0.029)	26.711 (0.144)	25.479 (0.184)	31.28 (0.052)
LB ² (20)	21.444 (0.371)	36.965 (0.012)	56.363 (0.000)*	60.027 (0.000)*
1999-2001	¥/€	¥/\$	¥/£	¥/CHF
Stock Returns				
JB	53	47	49	47
LB(20)	26.779 (0.142)	19.037 (0.519)	18.436 (0.559)	18.984 (0.523)
LB ² (20)	16.558 (0.681)	16.617 (0.678)	16.666 (0.675)	16.984 (0.654)
Exchange Rates				
JB	27	38	39	24
LB(20)	19.029 (0.520)	23.154 (0.281)	13.439 (0.858)	18.985 (0.523)
LB ² (20)	15.846 (0.726)	15.85 (0.726)	10.015 (0.968)	16.984 (0.654)
Cross Products				
LB(20)	29.685 (0.075)	15.131 (0.769)	25.552 (0.181)	27.177 (0.130)
LB ² (20)	8.7263 (0.986)	8.3058 (0.990)	13.934 (0.834)	25.255 (0.192)
2002-2006	¥/€	¥/\$	¥/£	¥/CHF
Stock Returns				
JB	49	56	58	59
LB(20)	18.175 (0.576)	9.7344 (0.973)	10.083 (0.967)	9.7879 (0.972)
LB ² (20)	11.799 (0.923)	9.5823 (0.975)	8.9081 (0.984)	9.1307 (0.981)
Exchange Rates				
JB	133	138	210	14
LB(20)	33.128 (0.033)	14.661 (0.0795)	38.73 (0.007)*	108.15 (0.081)
LB ² (20)	14.095 (0.826)	15.632 (0.739)	19.803 (0.470)	21.138 (0.389)
Cross Products				
LB(20)	22.665 (0.306)	11.788 (0.923)	26.826 (0.140)	23.449 (0.267)
LB ² (20)	6.4011 (0.998)	4.5495 (1.000)	7.5342 (0.995)	8.6938 (0.986)

*LB²(17):21.662(0.198); LB²(47):71.638(0.012); LB(19):35.643(0.012)

Table 23 Diagnostic Test on EGARCH models

UK				
1996-1998	£/\$	£/¥	£/CHF	£/DM
Stock Returns				
JB	10	8	6	7
LB(20)	47.888 (0.000)*	47.738 (0.000)*	44.158 (0.001)*	45.919 (0.000)*
LB ² (20)	58.783 (0.01)	11.777 (0.924)	12.154 (0.911)	11.437 (0.934)
Exchange Rates				
JB	76	86	95	29
LB(20)	24.07 (0.239)	18.808 (0.534)	13.424 (0.858)	14.581 (0.800)
LB ² (20)	17.066 (0.649)	17.252 (0.637)	23.698 (0.256)	18.187 (0.575)
Cross Products				
LB(20)	26.58 (0.148)	26.051 (0.164)	25.491 (0.183)	34.752 (0.021)
LB ² (20)	10.934 (0.948)	15.851 (0.726)	16.253 (0.701)	8.8589 (0.984)
1999-2001	£/€	£/\$	£/¥	£/CHF
Stock Returns				
JB	234	202	207	206
LB(20)	26.745 (0.143)	30.979 (0.055)	25.967 (0.167)	29.358 (0.081)
LB ² (20)	5.7629 (0.999)	6.2182 (0.999)	5.4999 (0.999)	6.4189 (0.998)
Exchange Rates				
JB	8	24	3223	22
LB(20)	24.57 (0.218)	23.766 (0.253)	29.275 (0.082)	16.863 (0.662)
LB ² (20)	36.393 (0.014)	32.442 (0.039)	30.984 (0.055)	9.0466 (0.982)
Cross Products				
LB(20)	26.884 (0.139)	31.666 (0.047)	21.115 (0.390)	18.832 (0.533)
LB ² (20)	7.9564 (0.992)	15.329 (0.757)	4.0625 (1.000)	5.4335 (0.999)
2002-2006	£/€	£/\$	£/¥	£/CHF
Stock Returns				
JB	23	15	18	18
LB(20)	26.756 (0.142)	24.823 (0.208)	28.599 (0.096)	25.534 (0.182)
LB ² (20)	21.107 (0.391)	25.827 (0.172)	20.965 (0.399)	20.784 (0.410)
Exchange Rates				
JB	67	41	40	10
LB(20)	24.17 (0.235)	23.881 (0.248)	14.056 (0.826)	24.817 (0.209)
LB ² (20)	37.431 (0.010)	8.4694 (0.988)	8.8236 (0.985)	11.119 (0.943)
Cross Products				
LB(20)	15.163 (0.767)	21.101 (0.391)	26.346 (0.155)	17.58657 (0.619)
LB ² (20)	14.253 (0.817)	21.698 (0.357)	36.9 (0.012)	9.869 (0.994)

*LB(36):58.783(0.01); LB(35):54.471(0.01); LB(26):44.940(0.012);LB(33):54.145(0.012)

Table 24 Diagnostic Test on EGARCH models

US				
1996-1998	\$/£	\$/¥	\$/CHF	\$/DM
Stock Returns				
JB	65	68	83	59
LB(20)	21.725 (0.356)	23.438 (0.268)	19.656 (0.480)	19.921 (0.463)
LB ² (20)	11.428 (0.934)	13.012 (0.877)	11.334 (0.937)	14.469 (0.806)
Exchange Rates				
JB	107	343	170	62
LB(20)	21.159 (0.388)	19.364 (0.498)	12.969 (0.879)	14.482 (0.805)
LB ² (20)	21.159 (0.780)	8.499 (0.988)	12.15 (0.911)	40.929 (0.004)*
Cross Products				
LB(20)	21.05 (0.394)	20.279 (0.441)	12.649 (0.892)	24.885 (0.206)
LB ² (20)	4.575 (1.000)	2.4032 (1.000)	9.0539 (0.982)	13.222 (0.868)
1999-2001	\$/€	\$/£	\$/¥	\$/CHF
Stock Returns				
JB	76	81	96	71
LB(20)	19.532 (0.488)	19.67 (0.479)	20.675 (0.416)	21.004 (0.397)
LB ² (20)	11.639 (0.928)	14.04 (0.828)	15.032 (0.775)	12.9 (0.882)
Exchange Rates				
JB	33	8	53	30
LB(20)	31.226 (0.052)	20.37 (0.435)	21.298 (0.380)	26.351 (0.155)
LB ² (20)	30.887 (0.057)	40.126 (0.005)*	17.674 (0.609)	17.541 (0.618)
Cross Products				
LB(20)	31.403 (0.050)	35.834 (0.016)	31.644 (0.047)	51.048 (0.123)
LB ² (20)	21.925 (0.345)	17.642 (0.611)	70.464 (0.000)*	27.469 (0.123)
2002-2006	\$/€	\$/£	\$/¥	\$/CHF
Stock Returns				
JB	2	2	2	2
LB(20)	30.322 (0.065)	30.579 (0.061)	31.15 (0.053)	30.37 (0.064)
LB ² (20)	37.394 (0.01)	36.853 (0.012)	33.944 (0.027)	37.26 (0.011)
Exchange Rates				
JB	7	24	165	9
LB(20)	27.634 (0.118)	18.196 (0.578)	16.158 (0.707)	27.059 (0.134)
LB ² (20)	26.3 (0.156)	79.138 (0.000)*	15.104 (0.770)	22.776 (0.300)
Cross Products				
LB(20)	13.342 (0.862)	27.081 (0.133)	28.998 (0.088)	9.7734 (0.972)
LB ² (20)	21.508 (0.368)	43.29 (0.000)*	27.996 (0.110)	22.778 (0.300)

*LB²(6):5.044; LB(9):18.533(0.029); ;B(4):7.545(0.01);LB²(16):7.66(0.958);LB(5):6.097(0.297);
LB(5):1.5454(0.908)